

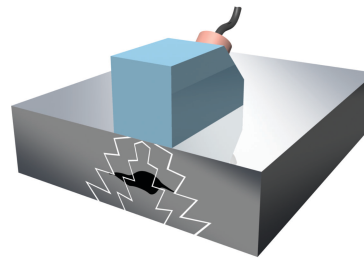
# Online Monitoring for Advanced Reactors

Jamie Coble  
Assistant Professor  
Southern Company Faculty Fellow  
Nuclear Engineering  
University of Tennessee

# The current approach to maintaining component health in NPPs

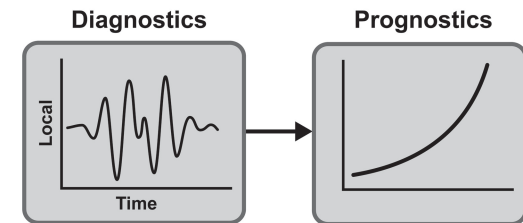
## Active Components: The Maintenance Rule

- Performance-based approach to equipment monitoring and maintenance
- Condition assessment methods (online and offline tests) are well developed for many key active components
- Currently a push to risk-informed regulation, operations, inspection and maintenance ...



## Passive Components: Aging Management Plans

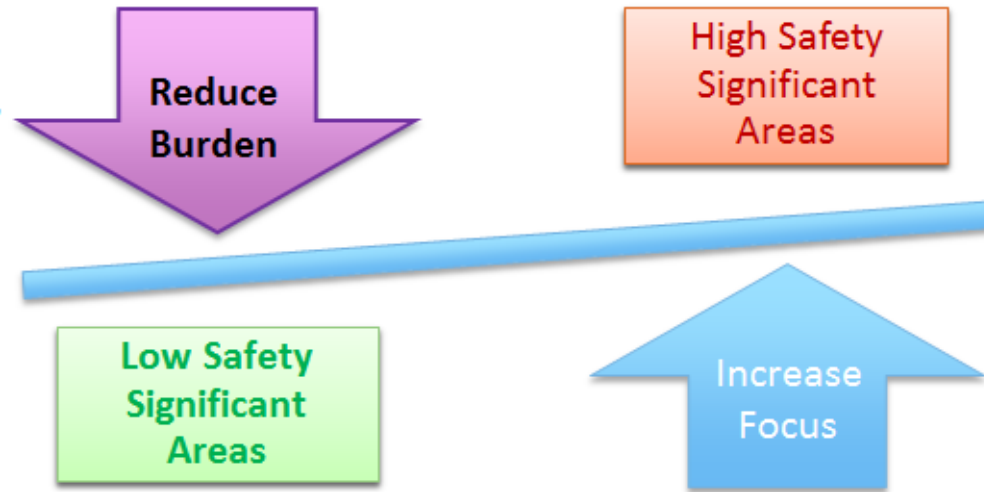
- In-service Inspection
  - Frequency prescribed by AMP
  - Nondestructive evaluation methods given by ASME BPV code, section XI



# New risk-informed approach to extend periodic inspection and maintenance activities (50.69)

**Provide Flexibility to Reduce Cost and Improve Plant Operations & Safety Margins**

It has the potential to provide the industry substantial cost savings and drive the goals of the *Delivering the Nuclear Promise* Initiative



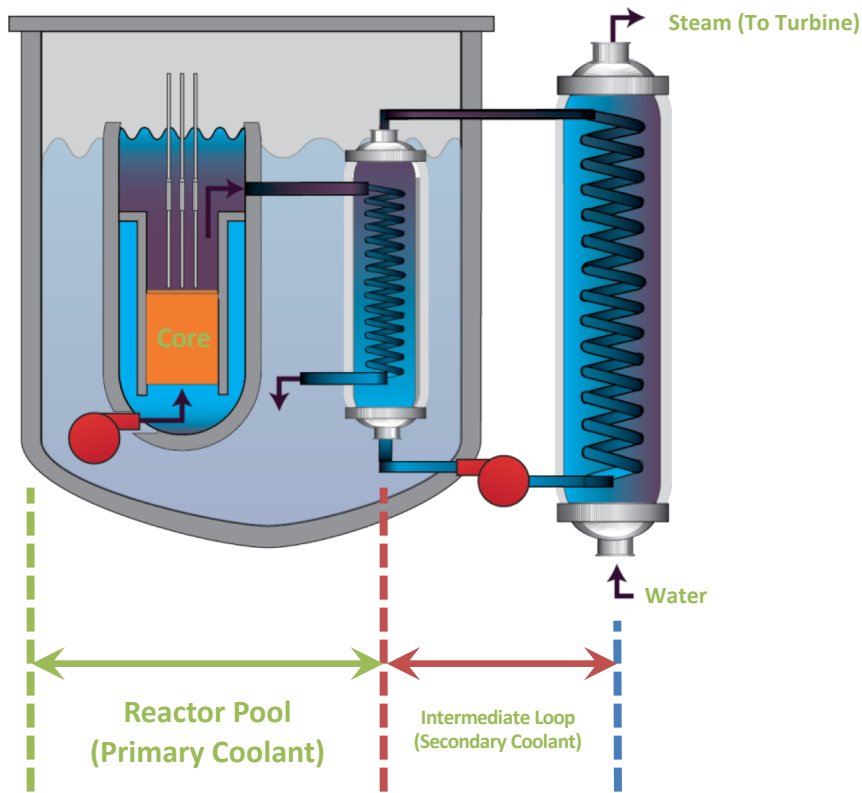
Source: Nuclear Energy Institute (NEI), [www.nei.org](http://www.nei.org)

# Advanced reactors operate in different regimes than our current LWRs

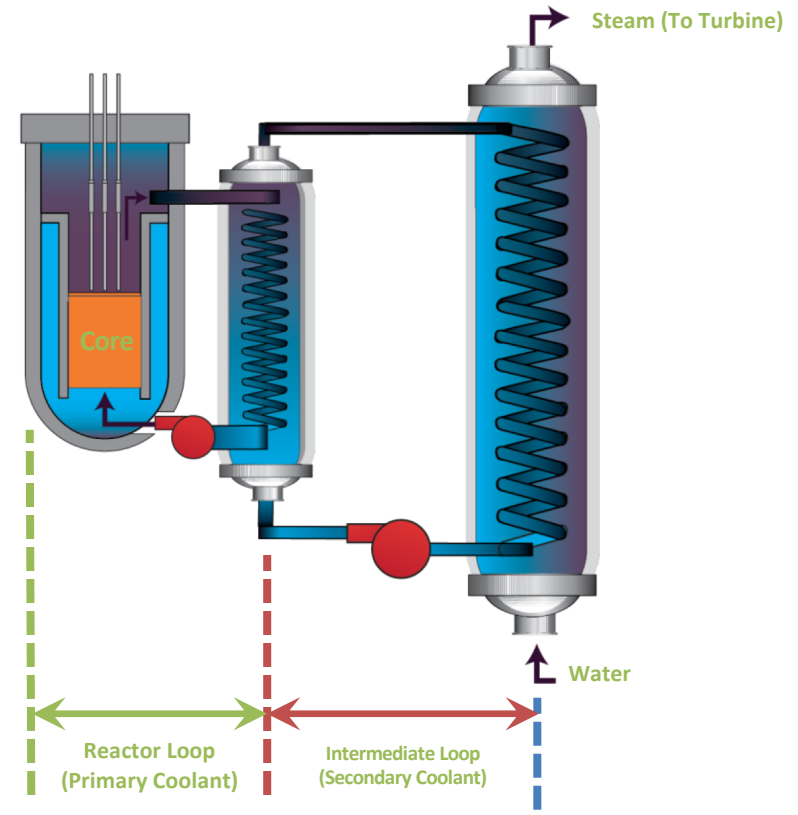
Reactor	Neutron Spectrum	Coolant	Core Outlet Temperature (°C)	Pressure (MPa)	Size (MWe)
<b>Current LWRs</b>	Thermal	Water	285-330	15.5 (PWR) 7 (BWR)	1000-1200
<b>Very-High-Temperature Reactor</b>	Thermal	Helium	900-1000	7-17	250-300
<b>Sodium-Cooled Fast Reactor</b>	Fast	Sodium	500-550	atm	50-150 300-1500 600-1500
<b>Supercritical-Water-Cooled Reactor</b>	Thermal/ Fast	Water	510-625	25	300-700 1000-1500
<b>Gas-Cooled Fast Reactor</b>	Fast	Helium	850	9	1200
<b>Lead-Cooled Fast Reactor</b>	Fast	Lead	480-570	atm	20-180 300-1200 600-1000
<b>Molten Salt Reactor</b>	Thermal/ Fast	Fluoride Salts	700-800	< 5	1000

# Pool-Type vs. Loop-Type Reactors

Pool



Loop



# Features of Advanced Reactor Designs lead to new requirements for OLM

## Reduced accessibility

pool-type designs  
sealed systems  
remote siting



## New component designs

Longer periods between  
inspection and maintenance  
opportunities



## New concepts of operation

multi-modular operation  
fluctuating generation demands  
co-generation



- *In situ* monitoring systems
- Long-lived, harsh-environment sensors
- Centralized off-site monitoring
- Greater situational awareness
- Physics-of-failure simulation models
- Real-time, continuous monitoring and condition assessment
- Integrate into supervisory control and O&M planning
- Accurately quantify and manage uncertainty throughout lifecycle

# Current condition assessment does not satisfy the real needs of OLM and PHM in Advanced Reactors

- Nondestructive **measurement** methods and analyses to detect degradation and anomalies
- **Algorithms** to characterize and monitor the degradation state of the component
- **Prognostics** that use the degradation state information to determine remaining useful life (RUL) and probability of failure (POF) of components
- Methods to **integrate monitoring results** into risk estimates, operations and maintenance planning, and advanced control algorithms

# Research and Development needs for Advanced Reactor OLM - **Sensors**

- Sensors and measurements to assess condition
  - Measurement modes to detect relevant degradation precursors
  - Long-lived, harsh environment sensors
- Optimal sensor placement
  - Risk-informed placement
  - Detectability and diagnosability



# Research and Development needs for Advanced Reactor OLM – **Models and Algorithms**

- High-fidelity physics of failure models for new component designs
- Monitoring and prognostics during normal operational transients
- Algorithms to mine information from **large data** and **big data**
  - Feature engineering for health indicators
  - Uncover significant maintenance relationships

# Research and Development needs for Advanced Reactor OLM – **Operation and Regulation**

- Accurate uncertainty quantification
- Online OLM performance metrics
- Integration of PHM results into risk assessment, O&M planning, and optimal control
- Verification and validation methodologies

# Questions?

[jamie@utk.edu](mailto:jamie@utk.edu)